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(54) **Tomographic apparatus having an array of detectors of uniform size**

(57) A source 1 of penetrating radiation forms a fan beam 2 to irradiate a body 8 and an array 3 of equi-sized detectors extending across the beam. The outputs of groups of the detectors are summed to provide a desired resolution. The resolution may vary across the array, e.g. by having more detectors in groups near the ends of the array than in groups nearer the centre.

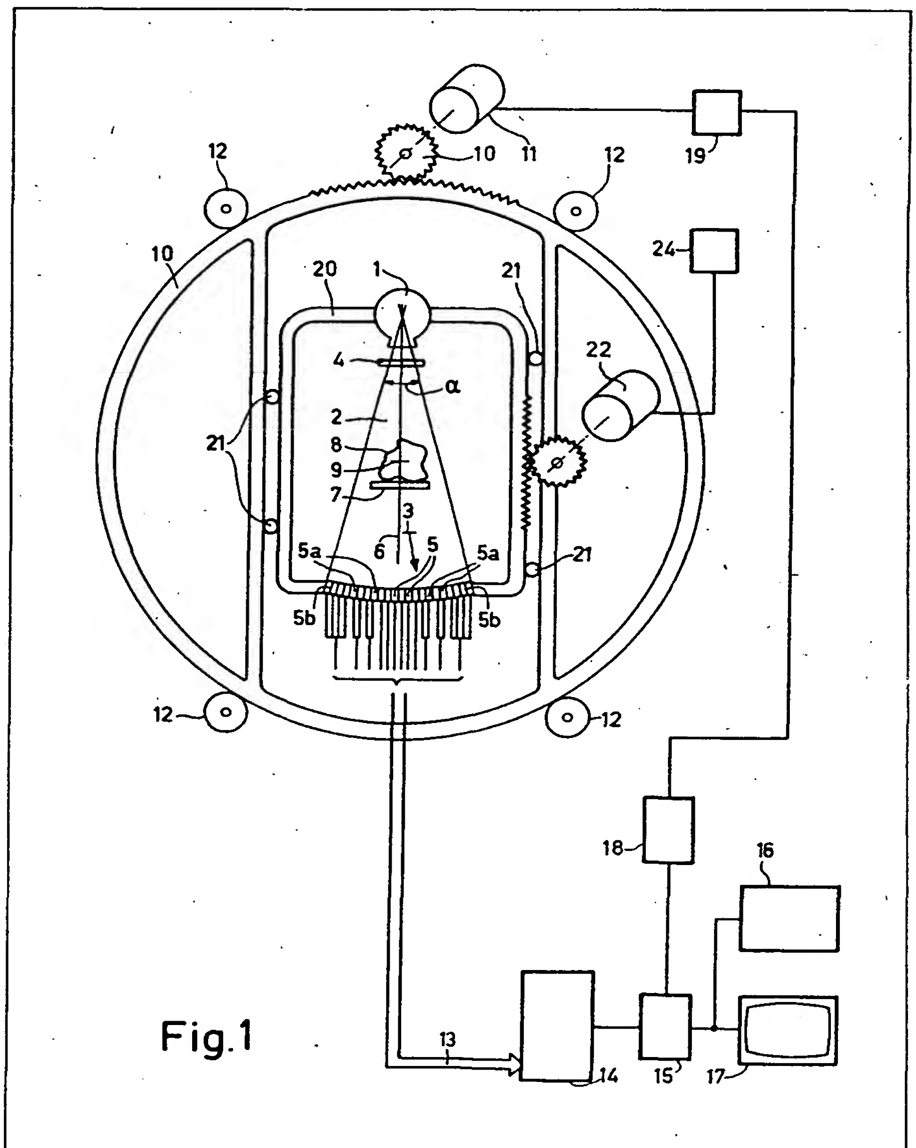

Fig.1

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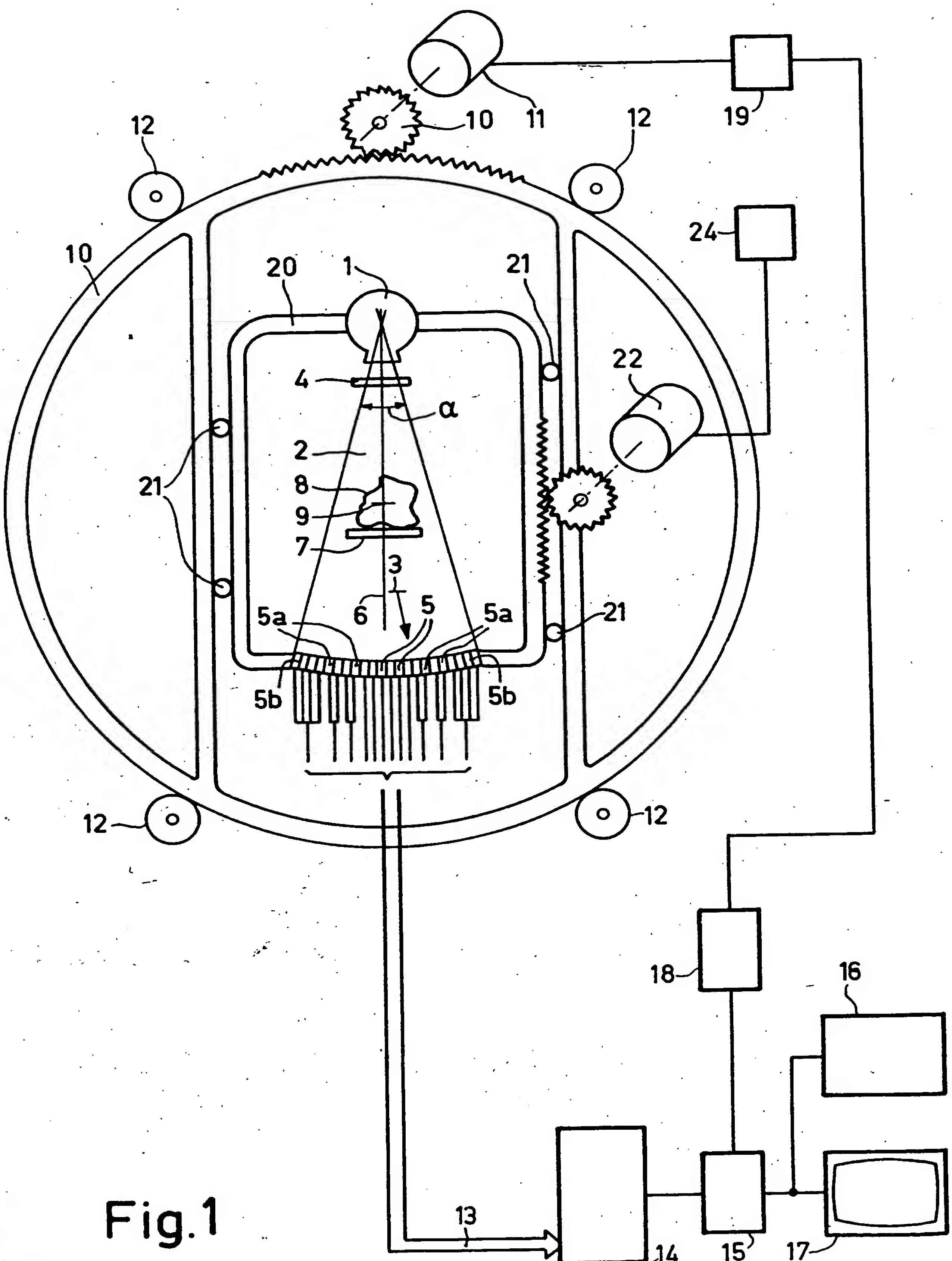

Fig.1

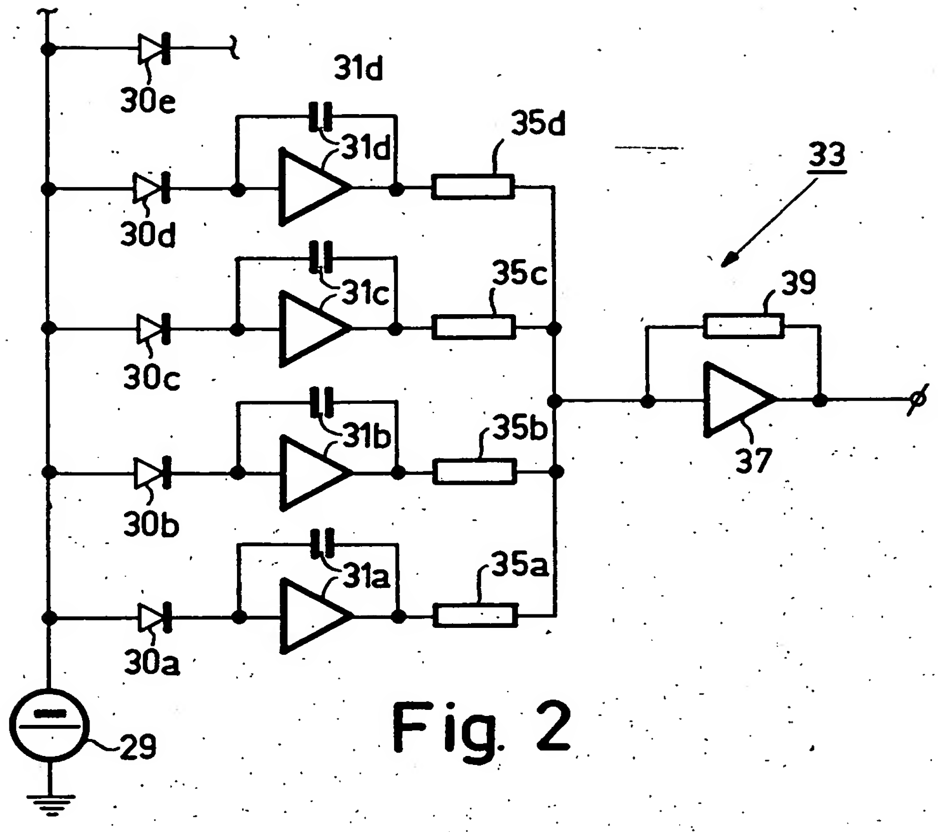
30e
31d
30d
31d
35d
33
30c
31c
35c
39
31b
35b
30b
37
31a
35a
30a
29

Fig. 2

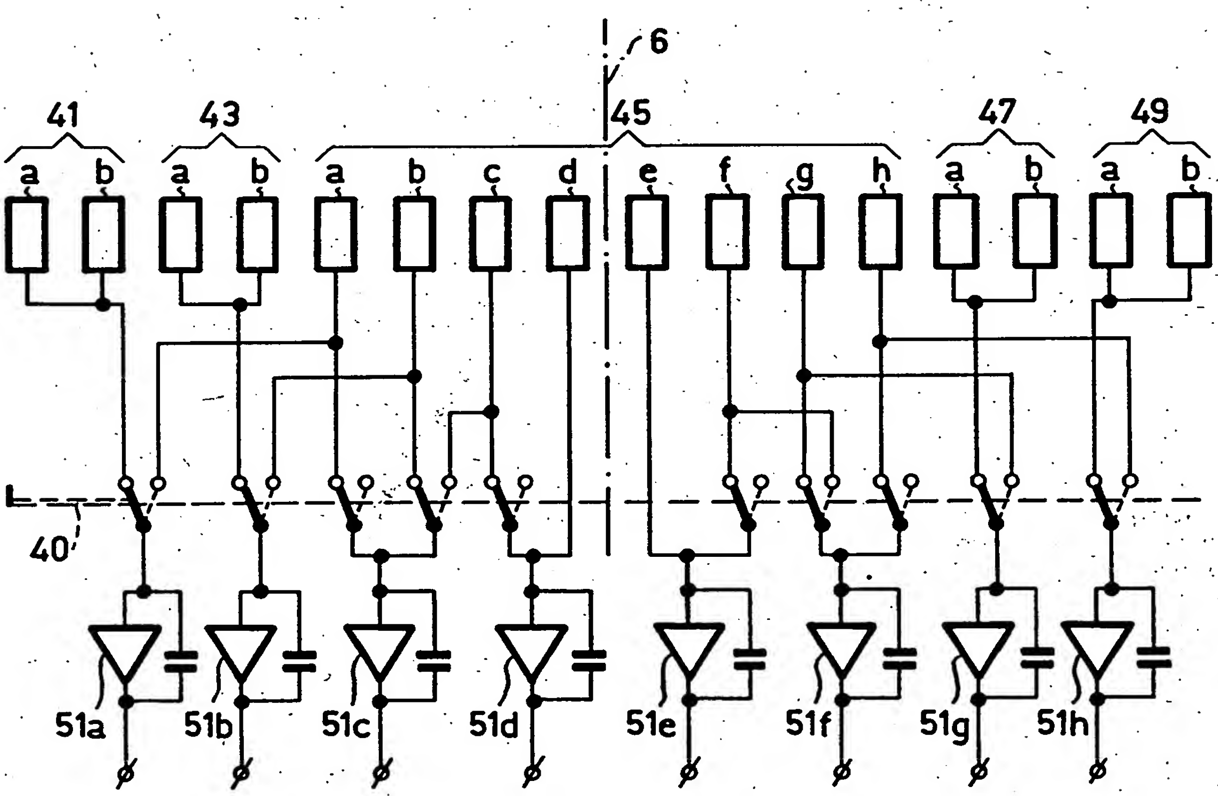
6
41
43
45
47
49
a
b
a
b
a
b
c
d
e
f
g
h
a
b
a
b
40
51a
51b
51c
51d
51e
51f
51g
51h

Fig. 3

SPECIFICATION

Device for det rmining l cal absorption values in a b dy secti n, and an array of d tect rs for such a d vice

The invention relates to a device for determining local absorption values in a section of a body by plural absorption path measurements and subsequent computation, comprising at least one radiation source for generating a fan-shaped beam of radiation which irradiates the body, and an array of detectors for detecting radiation which passes through the body in various directions, the direction of the radiation lying in the body section, the radiation source and the array of detectors being situated opposite each other on either side of a central axis through the body to be examined, those detectors on or near a central beam axis passing from the radiation source through said central axis, having a smaller detection surface area than those detectors which are situated further from said central beam axis, a detector output signal from any detector in the array being electrically distinct from the detector output signal from any other said detector. The invention furthermore relates to an array of detectors for such a device.

A device of the kind referred to above, is known from United States Patent Specification 3, 973,128. This Specification describes an arrangement in which the spatial resolution of the absorption distribution over the irradiated section to be reconstructed is position-dependent. The detector array is made up of detectors whose detection surface areas facing the body are not all the same. At the ends of the array of detectors, the detection surface areas are made larger than the detection surface areas provided at or near the centre of the array, with the result that the spatial resolution at the centre of the reconstructed absorption distribution is higher than that at the edge. The invention has for an object to provide an improved device of the kind referred to in which the area of the detector surfaces of the detectors, and as a result the spatial resolution in the computed reconstruction of the absorption distribution, can be readily adapted to the nature of the body section to be examined.

According to the invention there is provided a device for determining local absorption values in a section of a body by plural absorption path measurements and subsequent computation, comprising at least one radiation source for generating a fan-shaped beam of radiation which irradiates the body, and an array of detectors for detecting radiation which passes through the body in different directions, the direction of the radiation lying in the body section, the radiation source and the array of detectors being situated opposite each other on either side of a central axis through the body to be examined, those detectors on or near a central beam axis passing from the radiation source through said central axis, having a smaller detection surface area than those detectors which are situated further from said central beam axis, a detector output signal from any detector in the array being electrically distinct from the det ctor output signal from any other said detector, characterized in that the array of detectors comprises, viewed along the length of th array, a series of consecutively arranged detector elements which are uniform with respect to dimension and response behaviour, the detection surface of at least one said detector being formed by an integral multiple of the detection surface area of a detector element, the corresponding detector output signal being proportional to the sum of output signals from the individual detector elements grouped together to form said detector. Because all detector elements are of uniform size, the manufacture of an array of detectors made up of such detector elements can be cheaper than the manufacture of an array of unitary individual detectors having mutually different detection surface areas. The parallel connection of groups of detector elements need not be permanent. As a result, the electrical grouping together of detector elements can be changed in dependence on th nature of the body to be examined and the required quality of the computed image of the section of the body to be examined. It has been found that this is an advantageous facility, because for examinations performed on the human torso, it is usually sufficient to employ a resolution which is lower than that required, for example, for basicranial examinations.

The use hitherto, of an array of unitary individual detectors of mutually different dimensions gives rise to difficulties, notably when the detectors comprise respective ionisation chambers. Ionisation chambers of mutually different dimensions have mutually different response times and amounts of non-linearity. This makes the calibration and processing of the detector signals difficult.

To avoid this difficulty, a device embodying the invention is characterized in that each detector element is formed by an ionisation chamber. The construction of detectors having mutually different detection surface areas from different numbers of ionisation chambers, each of which has the same response behaviour, can provide the result that each resultant individual detector will have the same response time and amount and form of non-linearity, which is advantageous for the necessary calibration of the array of detectors.

In a further device embodying the invention, the outputs of the ionisation chambers associated with a single detector output are interconnected *via* electrically conductive connection means. The signal supplied by the detector output is the sum of the ionisation currents of the individual, parallel connected ionisation chambers. A known pre-amplifier which acts as an integrator may be connected to the parallel connection of the ionisation chambers.

Another device embodying the invention is characterized in that each detector element is connected to a corresponding integrator, there being provided for each detector output a summing circuit to which the outputs of the integrators of th ionisation chambers associated with that detector output, are connected *via* electrical connection means. In this embodim nt, the connection means are preferably constructed as switches. Such an arrangement of the el ctrical circuit connected to the

detector elements offer the advantage that the susceptibility to interference can be made less in comparison with a construction in which switches are directly connected to the outputs of th ionisation chambers. Since the ionisation currents will already have been integrated before they are applied to a summing circuit *via* the switches, the circuit will be less susceptible to electrical irregularities caused by the switches themselves. An array of detectors, which is composed of a series of uniform ionisation chambers and in which the spatial resolution is changed by the operation of switches, is advantageous for example where many different kinds of examination are to be performed. For example, a device embodying the invention can be used to examine part of the section to be examined with a high spatial resolution, while surrounding parts are examined at a lower spatial resolution. Furthermore, the same device can be used either to examine an entire body section at a low resolution (for example, during X-ray examination of large organs, such as lungs or liver), or at a high resolution (for example, basicranial X-ray examinations).

An embodiment of the invention will now be described by way of example, with reference to the accompanying diagrammatic drawings, of which:—

Figure 1 shows a device embodying the invention,

Figure 2 is a circuit showing the connections to part of a series of semiconductor detector elements for a device as shown in Figure 1, and

Figure 3 is an illustrative electrical connection diagram for a series of ionisation chamber detector elements for a device as shown in Figure 1.

Figure 1 shows diagrammatically an X-ray examination device embodying the invention, and comprising a radiation source 1 which preferably consists of an X-ray tube, but which may alternatively consist of, for example, a radio-active isotope such as Am241 or Gd153. An array of detectors *3*, for example, comprising 300 detector elements locally measures the intensity of a beam of X-radiation 2 emitted by the radiation source 1. The radiation source 1 in this case forms a fan-shaped beam 2 having an angle of aperture α which amounts to, for example, 60 degrees. The beam is caused to be substantially parallel in a direction perpendicular to the plane of the drawing and has a small thickness of, for example, from 3 to 15mm in that direction. A slit-like aperture 4 is provided for the formation of such a beam. The width dimension of detectors in the array *3* and the distance therebetween determine the feasible spatial resolution within a given beam angle of the fan-shaped beam 2. A supporting table 7, on which a body 8 to be examined is arranged, is longitudinally displaceable along a central axis 9 which is directed perpendicularly to the plane of the drawing. The system formed by the X-ray source 1 and the array of detectors *3* can be rotated about the central axis 9 and the body 8 by means of a toothed ring 10 which is driven by a motor 11 and which is supported by guides 12. Rotation of the system formed by the X-ray source 1 and the array of detectors *3* may be continuous or may alternatively be intermittent. In the latter case a rotational step is performed after each measurement in a given direction. A counter 18 counts the number of detector signals received during each measurement by an arithmetic device 15. When the count corresponds to the number of individual detector outputs, the control circuit 19 of the motor 11 is actuated for a brief period of time, so that a rotational step is effected. The system formed by the X-ray source 1 and the array of detectors *3* is supported on a frame 20. The frame 20 is movable on guide rollers 21 by means of a motor 22, so that the X-ray source 1 can be moved away from or towards the body along a central radiation beam axis represented by a connecting line 6. In this way the beam 2 generated by the X-ray source 1, and having an apex α, can always be made exactly to cover the body 8, so that optimum use is made of the array of detectors 3 during an examination. Prior to the start of a measurement, the distance between the X-ray source 1 and the body 8 is adjusted, for example, by manual operation of a control circuit 24.

Each of the detectors, e.g. 5, is connected, *via* a cable bundle 13, to an amplifier/converter 14 in which the detector signals are individually processed. The amplifier/converter 14 may comprise, for example, a multiplex circuit and an analog-to-digital converter. The output of the amplifier/converter 14 is connected to a computing device 15, whereby the local absorption is computed from the amplified- and converted detector signals. The computed absorption values are stored in a memory device 16 and, if desired, displayed on a display device 17.

The array of detectors *3* in an embodiment of the invention comprises a series of adjacently arranged detector elements which are uniform as regards dimensions and response behaviour. Preferably, the detector elements are ionisation chambers filled with a rare gas, such as xenon, and an extinction gas. The ionisation chambers are accommodated, for example, in a gastight housing and are formed by plate-shaped, parallel arranged, electrically conductive electrodes as proposed in U.K. Patent Application Number 13943/78 in the name of Applicant. Th detectors 5, situated in the vicinity of the central connecting line 6 at the centre of the X-ray beam 2, each comprise, for example, one ionisation chamber. Some detectors 5a which are situated to either side thereof each comprise two parallel connected ionisation chambers. Each of the detectors 5b situated at the respective ends of the array, comprises four parallel connected ionisation chambers. If the array of detectors *3* comprises, for example, 384 ionisation chambers and the overall detection arc subtends 48 degrees at the source 1, a practical construction of the detectors is as follows:

On either side of the central connecting line 6 from

0° - 15° : 8 detectors per degree (1 ionisation chamber/detector)

15° - 18° : 4 detectors per degree (2 ionisation chambers/detector)

18° - 21° : 2 detectors per degree (4 ionisation chambers/detector)

21° - 24° : 1 detector p r degree (8 ionisation chambers/detector)

The total number of detectors then amounts to 282, whilst the total number of ionisation chambers amounts to 384.

The signal-carrying electrodes of the ionisation chambers associated with an individual detector can readily be interconnected electrically. An alternative manner of arranging for the parallel operation of a group of detector elements is shown in Figure 2. The detector elements to be used have already been proposed in U.K. Patent Application Number 11665/78 in the name of Applicant. A series of detector elements 30a .... e, each of which comprises a semiconductor diode, is connected to a power supply source 29. The detector elements 30a ... e shown form only a fraction of the number of detector elements used. Each of the detector elements 30a ... *d*, which are grouped together to constitute a detector, is connected to a corresponding integrator 31a ... *d* which comprises an operational amplifier and a capacitor. The output of the integrators 31a ... *d* are connected to a summing circuit *33*. The summing circuit *33* comprises input resistors 35a ... d which all have the same resistance, an operational amplifier 37, and a feedback resistor 39. The output signal of the summing circuit *33* is the output signal of the detector which is proportioned as four detector elements operating in parallel. Depending on the position of a detector in the array of detectors *3*, 1, 2, 4, or 8 detector elements are connected via respectivel integrators to a corresponding summing circuit.

Figure 3 shows a schematic electrical connection diagram for a series of ionisation chambers 41a, b; 43a, b; 45a ... h; 47a, b and 49a, b for a device embodying the invention. Figure 3 only shows a number of ionisation chambers (16) which is small in comparison with the greater number of, often more than 300, ionisation chambers used in practice. The a-sections and the b-sections of the respective pairs of ionisation chambers 41a, b; 43a, b; 47a, b and 49a, b are permanently connected in parallel and form four detectors. The ionisation chambers are symmetrically arranged with respect to the central connecting line 6 which is also shown in Figure 1. By means of a two-position switch 40, the ionisation chambers can be connected to integrators 51a ... h in either of two ways. In the position shown of the switches 40 of the said pairs of ionisation chambers 41a, b; 43a, b; 47a, b; and 49a, b each form a detector which is connected to a corresponding integrator 51a, b, g and h. Each of the respective pairs of ionisation chambers 45a and b, c and d, e and f, g and h also forms a corresponding detector, and is connected to a corresponding 51c, d, e and f, respectively. The array of detectors thus comprises 8 detectors, each of which comprises two parallel connected ionisation chambers.

When the switch 40 is switched over, the ionisation chambers 45a, b, c, d, e, f, g and h are connected to the integrators 51a, b, c, d, e, f, g and h, respectively. The array of detectors again comprises 8 detectors, but in this case each detector is formed by only one ionisation chamber. Therefore, switching over can be used to mak a choice between a long array of detectors (low resolution) and a short array of detectors (high resolution), the number of individual det ctors being the same for both arrays. The short array of detectors will subtend a smaller angle α at the source 1 (see Figure 1) than a long array of detectors. The fan angle α of the radiation beam 2 can be adapted to th length of the array of d tectors *3* by using an appropriate aperture assembly 4.

In Figure 3, the switch 40 is connected directly to the detector element (ionisation chambers). It will be apparent that a respective integrator can alternatively be connected to each detector element (Figure 2) and the corresponding switch connected to the output thereof in order to establish or interrupt, as desired the connections between the outputs of the integrators and the corresponding summing circuits. An input resistor forming part of the summing circuit may be permanently connected to each output of the integrators, a switch such as the switch 40 being connected to said input resistors in order to establish the desired connections to the remaining part of the corresponding summing circuits.

CLAIMS

1. A device for determining local absorption values in a section of a body by plural absorption path measurements and subsequent computation, comprising at least one radiation source for generating a fan-shaped beam of radiation which irradiates the body, and an array of detectors for detecting radiation which passes through the body in different directions, the direction of the radiation lying in the body section, the radiation source and the array of detectors being situated opposite each other on either side of a central axis through the body to be examined, those detectors on or near a central beam axis passing from the radiation source through said central axis, having a smaller detection surface area than those detectors which are situated further from any detector in the array being electrically distinct from the detector output signal from any other said detector, characterized in that the array of detectors comprises, viewed along the length of the array, a series of consecutively arranged detector elements which are uniform with respect to dimension and response behaviour, the detection surface of at least one said detector being formed by an integral multiple of the detection surface area of a detector element, the corresponding detector output signal being proportional to the sum of output signals from the individual detector elements grouped together to form said detector.

2. A device as claimed in Claim 1, characterized in that the detetcor elements are ionisation chambers.

3. A device as claimed in Claim 1 or 2, characterized in that the outputs of the detector elements grouped together to form a detector are interconnected by electrical connection means.

4. A device as claimed in Claim 1 or 2, characterized in that each detector element is connected to a corresponding integrator, there being provided for each detector formed by a plurality of detector elements a summation circuit to which the outputs of said integrators of the detector elements forming said detector are connected *via* electrical connection means.

5. A device as claimed in Claim 3 or Claim 4, characterized in that said electrical connection means are formed by switches.

6. An array of detectors comprising a plurality of ionisation chambers which are uniform with respect to dimension and respons behaviour, and electrical c nnection means arranged to connect at least one selected group of adjacent said ionisation chambers together in parallel, for use in a device as claimed in any one of the Claims 1 to 5.

7. An array of detectors comprising a plurality of ionisation chambers which are uniform with respect to dimension and response behaviour, a corresponding integrator connected to the output of each said ionisation chamber, and electrical connection means including summation circuits arranged to form a respective sum of the outputs of integrators connected to a corresponding selected group of adjacent said ionisation chambers, for use in a device as claimed in any one of the Claims 1 to 5.

8. A device for determining local absorption values in a section of a body by plural absorption path measurements and subsequent computation, substantially as herein described with reference to the accompanying drawings.

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